Spanish Journal of Agricultural Research (2006) 4(4), 336-344

Effect of storage temperature on the flavour of citrus fruit

A. Marcilla[1]*, M. Zarzo[2] and M. A. del Río[1]

[1] *Valencian Institute of Agricultural Research (IVIA). Ctra. Moncada-Náquera, km 4,5. 46113 Moncada (Valencia). Spain*

[2] *Polytechnic University of Valencia. Camino de Vera, s/n. 46022 Valencia. Spain*

Abstract

This paper reports the effect of different storage temperatures (5, 15, 20 and 25ºC) on the flavour of cv. Valencia Late Frost oranges stored for up to one month (following a pre-experimental two month storage period at 5ºC). Samples were instrumentally analysed every week for titratable acidity, soluble solid content, maturity index, and ethanol and acetaldehyde contents. In addition, four sensory attributes were assessed by 20 taste panellists (this work formed part of their training): acidity, maturity index, off-flavours and orange-like flavour. Principal components analysis was performed to determine the correlation structure of the sensorial data. This showed that the presence of off-flavours reduced the orange-like flavour perceived, but affected neither the acidity nor the maturity index. Acidity correlated negatively with the sensorially-perceived maturity index. The higher temperatures reduced the orange-like flavour and increased the presence of off-flavours over storage; this had a negative impact on the sensorial quality of the fruit. These effects were statistically significant, though more accurate results may have been obtained had the panellists received more training.

Additional key words: acetaldehyde, ethanol, sensory evaluation, training taste panellists.

Resumen

Efecto de la temperatura de almacenamiento en el sabor de los cítricos

El efecto de distintas temperaturas de almacenamiento (5, 15, 20 y 25ºC) en la calidad del sabor en naranjas cv. Valencia Late Frost fue estudiado periódicamente durante un mes (después de estar almacenadas durante 2 meses a 5°C). Las muestras fueron semanalmente analizadas midiendo la acidez, el contenido en sólidos solubles, el índice de madurez y contenido en etanol y acetaldehído. Esta experiencia formó parte de la sesiones de entrenamiento de un panel de catadores. Cuatro atributos sensoriales fueron evaluados por el panel: acidez, índice de madurez, malos sabores y el sabor característico a naranja. Se realizó un análisis de componentes principales para estudiar la estructura de correlación de los datos sensoriales. Este análisis reveló que la presencia de malos sabores redujo el sabor característico a naranja percibido por el panel, pero no afectó a la acidez ni al índice de madurez. Por otro lado, la acidez tuvo una correlación negativa con el índice de madurez percibido sensorialmente. Según los resultados, las altas temperaturas redujeron el sabor característico a naranja y aumentaron los malos sabores a lo largo del almacenamiento, los cuales impactaron negativamente en la calidad sensorial de las naranjas. Estos efectos resultaron estadísticamente significativos, aunque probablemente se hubieran obtenido resultados más exactos con sesiones adicionales de entrenamiento del panel.

Palabras clave adicionales: acetaldehído, entrenamiento de catadores, etanol, evaluación sensorial.

Introduction

Spain, with a production of more than 3 million tons of oranges per year, is the foremost producer of this fruit in Europe and the fourth most important worldwide (www.mapa.es). Most Spanish oranges are consumed fresh.

* Corresponding author: amarcill@ivia.es
Received: 08-11-05; Accepted: 17-10-06.

Many authors have studied the organoleptic characteristics of fruits such as peach (Gorny *et al*., 1999; Cascales *et al*., 2005), melon (Guerineau *et al*., 1999), strawberry (Pianezzola *et al*., 1999) and apple (Corrigan *et al*., 1997; Vaysse *et al*., 1998; Lavilla *et al*.,1999; Hampson *et al*., 2000; Lateur *et al*., 2001; Echevarría *et al*., 2004). However, few studies have been conducted on citrus fruits, despite their world scale importance. Generally, consumer acceptance of citrus fruits is defined by their aroma, taste and chewiness. The aroma is produced by characteristic volatile compounds (Sala, 1987). Bitterness, a characteristic of the Navel cultivar, depends on the limonin content. The typical sour-sweet taste of citrus fruits is determined by the relationship between the soluble solid content (SSC) and the titratable acidity (TA). Organic acids predominate in unripe citrus fruits, which give them a sour taste unacceptable to consumers. In contrast, the content of organic acids is low in ripe fruits, which are perceived as sweet. Sugars and acids are the main markers of citrus fruit quality. These compounds can serve as respiratory substrates, and consequently their concentration over storage depends on post-harvest conditions such as storage time, temperature, humidity, atmospheric control, the application of wax coatings, and the use of radiation to improve shelf life, etc.; the post-harvest development of citrus fruits can therefore significantly alter their commercial properties (Echeverría and Ismail, 1987).

Many authors have studied the effects of post-harvest treatments on citrus fruits in terms of gas permeability, weight loss, appearance, internal gas composition, and the presence of ethanol and acetaldehyde, etc. (Purvis, 1983; Pesis and Avissar, 1989; Shaw *et al*., 1991; Petracek *et al*., 1998; Peeples and Albrigo, 1999; Salvador, 1999; Perez-Gago *et al*., 2002; Porat *et al*., 2005). However, few have attempted to relate post-harvest conditions to fruit quality as measured by sensorial analysis performed by taste panellists (Hagenmaier and Baker, 1994; Mannheim and Soffer, 1996; Biolatto *et al*., 2005; Shi *et al*., 2005). As a result, the relationship between the quality perceived by consumers and the different sensorial attributes of citrus fruits is still poorly understood. Sensorial studies of fresh produce can be used to identify optimal harvest maturity, to evaluate flavour quality in breeding programs, to determine optimal storage and handling conditions, to assess the effects of disinfestation or preconditioning techniques on flavour quality, and to measure flavour quality over the post-harvest life of a product (Baldwin, 2002).

The main aim of the present study was to determine the effect of different storage times and temperatures on the sensorial attributes that determine the overall quality of orange fruits. A second objective was to elucidate the relationships between these sensorial attributes. The present work was undertaken as part of the training of taste panellists; a further goal was therefore to determine the level of agreement between the panel members.

Material and Methods

Plant material and storage conditions

Valencia Late Frost oranges were harvested and immediately selected for uniformity in size and absence of defects. The fruit was then stored at 5°C at a relative humidity of 85-90% for two months to ensure its availability at the beginning of the experimental period. After this initial storage period, the fruit was randomised into four lots of 70 oranges. One lot remained stored at 5ºC while the other three were stored at 15, 20 and 25ºC respectively. Fruit samples from each lot were analysed after 1, 2, 3 and 4 weeks of storage.

Chemical analysis

In each of the 16 treatments (4 storage temperatures at 4 storage periods), three samples of two oranges were taken. The juice from each was extracted using a rotary citrus squeezer and filtered through a 0.8 mm pore sieve. The soluble solid content (SSC) of the juice was determined using an Atago digital refractometer (DR-101) and expressed as a percentage of sucrose in an equivalent solution. Titratable acidity (TA) was determined from 5 ml aliquots by titrating with 0.1 N NaOH to pH 8.1; the results were expressed as grams of citric acid per 100 ml. The maturity index (MI) was calculated as the SSC/TA ratio. All determinations were performed in duplicate.

The ethanol and acetaldehyde concentrations were determined in juice samples from two fruits by head-space gas chromatography, as described by Ke and Kader (1990). Five millilitres of juice were transferred to 10 ml vials with crimp-top caps and Teflon (TFE)/silicone septum seals, and kept at –18ºC. Before instrumental analysis, the vials were maintained in a water bath at 20ºC for 1 h, followed by a further 10 min at 30ºC to reach gas equilibrium in the head-space. A 1 ml sample of this head-space volume was then withdrawn and injected into a gas chromatograph (Perkin-Elmer, Model 2000) equipped with a flame ionisation detector and a 1.2 m × 0.32 cm Porapack QS 80/100 stainless steel column. The injector was set at 175ºC, the column at 150ºC, the detector at 200ºC, and the carrier gas at 9.1 psi. Volatile compounds were identified and quantified by comparison of their retention times with standards. Results were expressed as mg/100 ml of juice. All determinations were performed in triplicate.

Sensorial evaluation

Eight oranges per storage temperature were sampled every week for assessment by a taster panel of 20 individuals (eleven women and nine men aged 21-60 years training to become citrus fruit tasters, all of whom were volunteers from among the staff of the IVIA Research Institute). Each orange was peeled and separated into its segments; each sample was identified by a random three-digit code. Three segments were placed in white pots and presented to the panellists.

At each weekly session, each panellist evaluated two samples for each storage temperature (i.e., they assessed eight samples per week). After assessing them for sensorially-perceived acidity and MI, they recorded their scores by making a mark on unstructured line scales. The left edges (value 0) corresponded to the absence of perceived acidity or low MI, and the right edge (value 15) to very high acidity or high MI. The intensity of off-flavours was scored on a 6-point category scale (0 = none and 5 = strong). Orange like-flavour was scored on a 9-point category scale (1,2,3 = low quality; 4,5,6 = acceptable quality and 7,8,9 = high quality). All sensory evaluations were conducted in individual booths under white light at room temperature. Mineral water was used as palate cleanser between samples (UNE 87023, 1979).

Statistical analysis

Analysis of variance (ANOVA) was performed on the results for each quality variable to determine the significance of the effects of storage time and temperature on fruit quality. Means were compared by the least significance difference (LSD) test. Significance was set at $P \leq 0.05$.

After averaging the two replicate measurements for SSC, TA and SSC/TA for each sample, 48 data were obtained corresponding to three samples for each of the 16 experimental conditions. These were analysed by multiple linear regression (MLR). All calculations were made using Statgraphics 5.1 software (www.statgraphics.com).

As a complementary test to help interpret the results of multivariate analysis, the correlation coefficient between each pair of variables was calculated. The average instrumental analysis result for each variable was calculated for each of the 16 conditions (4 temperatures × 4 storage periods), providing a matrix of 16 observations and 7 variables (time of storage, temperature, TA, SSC, MI, and the ethanol and acetaldehyde contents). Four additional variables – acidity, MI, off-flavours and orange-like flavours (the average values for the entire panel) – were included in this matrix.

The sensorial data were arranged in a matrix of 80 observations in rows (20 panellists by 4 temperatures) and 16 variables: TA_t, MI_t, $flavour_t$ and $off\text{-}flavours_t$, where t = the number of weeks of storage (1, 2, 3 or 4). To study the relationships between sensorial attributes, principal component analysis (PCA) was performed with this matrix using Unscrambler 9.0 software (www.camo.com). The data were centred and scaled to unit variance. Thus, each individual datum of the matrix was the average of two evaluations obtained per panellist in each of the 16 experimental conditions.

Results

Effect of storage time and temperatures on chemical variables

To provide reference values of fruit quality at the beginning and end of the experiment, TA, SSC and MI were also evaluated just after harvest and after two months of storage. Only small differences were found for all three, e.g., MI at harvest was 11.23 and 11.17 after 2 months storage at 5°C (Table 1).

According to the MLR results (Table 2), the storage period had no significant influence on TA. However, a negative correlation was identified between TA and the storage temperature. Storage temperature had no significant effect on SSC. However, after two weeks of storage a significant increase in SSC was observed at all temperatures. Both storage time and temperature had a significant effect on MI: MI values increased with temperature after two weeks of storage.

The effect of storage period on SSC and MI was assessed by means of MLR using the indicator variable «storage period > 2» (see Table 2). No significant differences were observed in the mean value of these variables between weeks 1 and 2, nor between weeks 3 and 4. However, significant differences were identified between weeks 1-2 and 3-4.

Table 1. Average values for the chemical variables of oranges cv. Valencia stored at 5, 15, 20 and 25°C for 1, 2, 3 and 4 weeks

	TA (mg/100 ml)	SSC (%)	MI	Acetaldehyde (mg/100 ml)	Ethanol (mg/100 ml)
At harvest	1.0	11.30	11.23	—	—
2 months at 5°C	0.97	10.89	11.17	—	—
Storage temperature					
5°C	0.87c*	10.59a	12.18a	0.50a	22.46a
15°C	0.76b	10.27a	13.51b	0.74b	38.84b
20°C	0.76b	10.50a	13.91b	1.01c	77.63c
25°C	0.69a	10.28a	14.89c	1.13d	107.68d
Storage period					
1 week	0.78a	9.61a	12.44a	12.44b	68.88b
2 weeks	0.77a	9.77a	12.74a	12.74b	75.92b
3 weeks	0.77a	11.15b	14.56b	0.77a	55.04a
4 weeks	0.76a	11.11b	14.75b	0.82ab	46.77a

* Means within the same storage temperature/period followed by the same small letters are not significantly different at $P \leq 0.0$. TA: titratable acidity. SSC: soluble solid content. MI: maturity index.

Temperature and storage period significantly effected the concentration of volatile compounds (Table 2). The ethanol and acetaldehyde contents decreased significantly after two weeks of storage, the highest values always seen at the highest temperatures. In all cases the average ethanol content was < 126 mg/100 ml (Table 1) – that of normal marketing conditions.

Effect of different storage periods, temperatures and panellist on sensorial attribute results

Panellist number 18 produced the numerical assessments closest to that of the panel average. To study the effect of each individual panellist on the sensorial attributes recorded, this panellist was taken as a reference and the remaining panellists were coded by creating new indicator variables (Pi). Multiple linear regression was then performed to determine the effect of temperature, storage time and panellist on sensorial attributes (Table 3). Sensorially-perceived MI and off-flavour significantly increased with storage time and temperature. The opposite was observed for acidity and orange-like flavour. The regression model for off-flavours was fitted with no constant and using the variables SP-1 (storage period 1) and ST-5 (storage temperature 5). Thus, the average score for off-flavours tended to zero in the first week of storage (SP = 1) and at a temperature of 5ºC (ST = 5).

The fruit stored at 25ºC had the highest off-flavour value (1.38) and the lowest orange-like flavour value (4.31). However, the former value of 1.38 corresponds to a low off-flavour intensity, and the four treatments

Table 2. Regression model for the chemical variables of oranges cv. Valencia stored at 5, 15, 20 and 25°C for 1, 2, 3 and 4 weeks

Regression equation of chemical parameters[a]		$R^{2\,b}$	p-val$_{max}$[c]	n_{out}[d]
TA (g/100 ml) =	0.887 – 0.00803 ST	56.7	< 0.0001	0
SSC (%) =	9.70 + 1.44 (SP > 2)	61.2	< 0.0001	0
MI =	10.48 + 2.06 (SP > 2) + 0.13 ST	63.4	< 0.0001	0
Ethanol (mg/100 ml) =	25.04 – 21.5 (SP > 2) + 0.15 ST^2	85.4	< 0.0001	0
Acetaldehyde (mg/100 ml) =	0.37 – 0.096 (SP > 2) + 0.032 ST	76.1	0.023[e]	0

[a] Regression equation to predict the average value of the chemical variables as a function of ST (temperature, ºC), SP (storage time, weeks) and (SP > 2) (indicator variable that takes the value 1 if SP > 2, and zero if otherwise). [b] Coefficient of determination (percentage of variance of the response variable explained by the model). [c] Maximum value of the observed level of significance associated with the regression coefficients included in the model. [d] Number of outliers discarded from the model. [e] P value corresponding to the coefficient of the indicator variable (SP > 2).

Table 3. Regression model for the sensorial attributes of oranges cv. Valencia stored at 5, 15, 20 and 25°C for 1, 2, 3 and 4 weeks

Regression equation for sensorial attributes[a]		R^2 [b]	R^2 [c]	p-val$_{max}$ [d]	n_{out} [e]
Sensorial MI =	$5.96 + 0.32\ SP + 0.046\ ST + 1.33\ (P_{10}+P_{15}) - 1.69\ P_{12} + 0.69\ (P_1+P_6+P_{11}+P_{19}) + 0.96\ (P_2+P_5+P_8+P_{13})$	49.3	17.5	<0 .0001	3
Sensorial acidity =	$6.93 - 0.28\ SP - 0.064\ ST - 3.1\ (P_3+P_8+P_{17}+P_{20}) - 2.03\ P_6 + 6.02\ P_7 + 1.57\ (P_1+P_2+P_5+P_{14}+P_{15}) + 3.62\ (P_9+P_{11}+P_{12}+P_{16})$	75.8	6.9	0.0013	1
Off-flavours =	$0.086\ (SP-1) + 0.036\ (ST-5) - 0.34\ (P_2+P_{17}+P_{19}) + 0.42\ (P_{10}+P_{11}+P_{20}) + 0.78\ (P_{13}+P_{16}) + 0.89\ P_{14}$	40.5	14.1	0.014[f]	4
Orange-like flavour =	$6.56 - 0.30\ SP - 0.054\ ST + 1.48\ (P_2+P_4) + 0.62\ (P_6+P_{11}+P_{19}) - 1.33\ (P_{10}+P_{17}) - 0.8\ (P_{13}+P_{14}+P_{20})$	49.2	15.8	0.0004	0

[a] Regression equation to predict the average sensorial attribute values as a function of ST and SP for an individual panellist *i* (for the panellist in question, $P_i = 1$; all other panellists take the value of zero). For example, the predicted sensorial acidity for panellist number 8 would be: 6.93 – 0.28 SP – 0.064 ST – 3.1. The average attributes for all panellists (panel average) can be estimated considering a null value for all indicator variables ($P_i = 0$). [b] Coefficient of determination (percentage of variance of the response variable explained by the model). [c] Coefficient of determination (R^2) if the indicator variables corresponding to the individual panellists (P_i) are not included in the model (this only applies to the sensorial attributes). [d] Maximum value of the observed significance level associated with the regression coefficients included in the model. [e] Number of outliers discarded from the model. [f] P value corresponding to the coefficient of SP-1.

produced fruit regarded by the panel as being of acceptable quality in terms of orange-like flavour (Table 4).

Relationship between chemical variables and sensorial attributes

Table 5 shows the correlation coefficient between each pair of variables. A statistically significant correlation was found between the orange-like flavour and all analytical variables except ethanol concentration. Thus, the content of ethanol was not responsible for orange quality. This variable was the most independent, showing the weakest lowest correlations with the remaining variables.

With respect to the PCA conducted with the sensory matrix, the first two principal components explained 53.1% of the total variance. The loading plot (Fig. 1) revealed the correlation structure among variables. The plot showed that off-flavours correlated negatively with orange-like flavour, and that the presence of off-flavours reduces fruit quality as perceived by the panel.

Table 4. Average sensorial atributes of oranges cv. Valencia stored at 5, 15, 20 and 25°C for 1, 2, 3 and 4 weeks

	Acidity	Sensorial MI	Off-flavours	Orange-like flavour
Storage temperature				
5°C	6.70b*	7.46a	0.36a	5.40b
15°C	6.71b	7.72a	0.43a	5.48b
20°C	5.51a	8.24b	0.90b	4.75a
25°C	5.58a	8.35b	1.22c	4.34a
Storage period				
1 week	7.08b	7.40a	0.75a	5.37b
2 week	6.09a	7.82ab	0.72a	5.03b
3 week	5.65a	8.19bc	0.62a	5.26b
4 week	5.69a	8.37c	0.82a	4.31a

* Means within the same storage temperature/period followed by the same small letters are not significantly different at $P \leq 0.05$.

Table 5. Correlation matrix for sensorial atributes and chemical variables[a] of oranges cv. Valencia stored at 5, 15, 20 and 25°C for 1, 2, 3 and 4 weeks[b]

	TA (g/100 ml)	SSC (%)	MI	Acetal-dehyde (g/100 ml)	Ethanol (g/100 ml)	Sensory acidity	Sensory MI	Off-flavours	Orange-like flavour
TA (g/100 ml)	1.00	—	—	—	—	—	—	—	—
SSC (%)	0.94	1.00	—	—	—	—	—	—	—
MI	–0.69	–0.66	1.00	—	—	—	—	—	—
Acetaldehyde (g/100 ml)	0.37	0.31	–0.71	1.00	—	—	—	—	—
Ethanol (g/100 ml)	–0.29	–0.34	0.18	0.55	1.00	—	—	—	—
Sensorial acidity	–0.47	–0.42	0.51	–0.73	–0.42	1.00	—	—	—
Sensorial MI	0.49	0.42	–0.63	0.90	0.51	–0.91	1.00	—	—
Off-flavours	0.80	0.85	–0.72	0.59	–0.053	–0.56	0.64	1.00	—
Orange-like flavour	–0.59	–0.54	0.52	–0.62	–0.22	0.68	–0.73	–0.80	1.00

[a] Each element r_{ij} of this matrix is the linear correlation coefficient of row i and column j. [b] $|r| > 0.47$ corresponds to a statistically significant correlation ($\alpha = 0.05$).

Sensorially-perceived acidity correlated negatively with the sensorial MI.

The score plot corresponding to this PCA analysis (Fig. 2) indicated that orange-like flavour was higher than average in fruits stored at 5ºC (most of these points are enclosed in the dashed ellipse) and lower than average for 25ºC (mainly situated within the dotted ellipse). Further, fruit stored at 25ºC tended to have a higher off-flavour score, although the ethanol content at this temperature decreased over storage (Table 1).

Discussion

This experiment was designed as part of the final training of a taster panel, whose members were learning to assess small differences in orange fruit quality (Meilgaard *et al*., 1999). After four additional weeks of storage at different temperatures, only small changes in chemical and sensorial attributes were detected, suggesting that the fruit quality was perfectly suitable for market. Storage time had no influence on TA, but its effect on the remaining instrumental parameters after two weeks of storage was significant (Table 2). Similar studies report that fruit quality can be properly preserved in cold conditions for long periods of time, resulting in only a small reduction in flavour quality (Abad *et al*., 2003), and a small increase in the volatile compound content (Martínez Jávega *et al*., 1991a; Baldwin *et al*., 1995; Mazzuz, 2001), weight loss, and MI (Martínez-Jávega *et al*., 1991b; Pozzan *et al*., 1993; Vázquez, 1994).

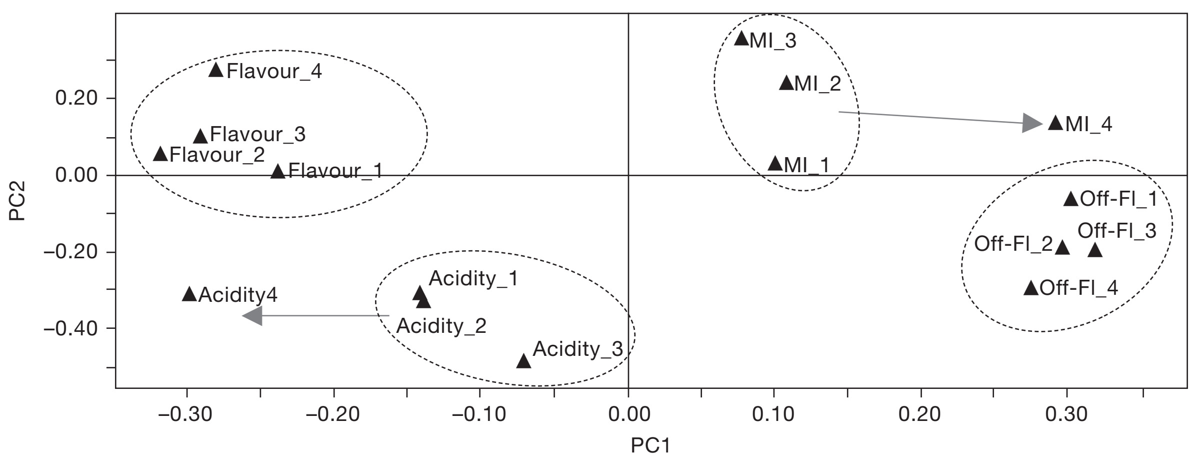

Figure 1. Loading plot corresponding to the two principal components of the sensorial data (PC1 and PC2 explain 53.1% of the total variance). The subscripts indicate the weeks of storage.

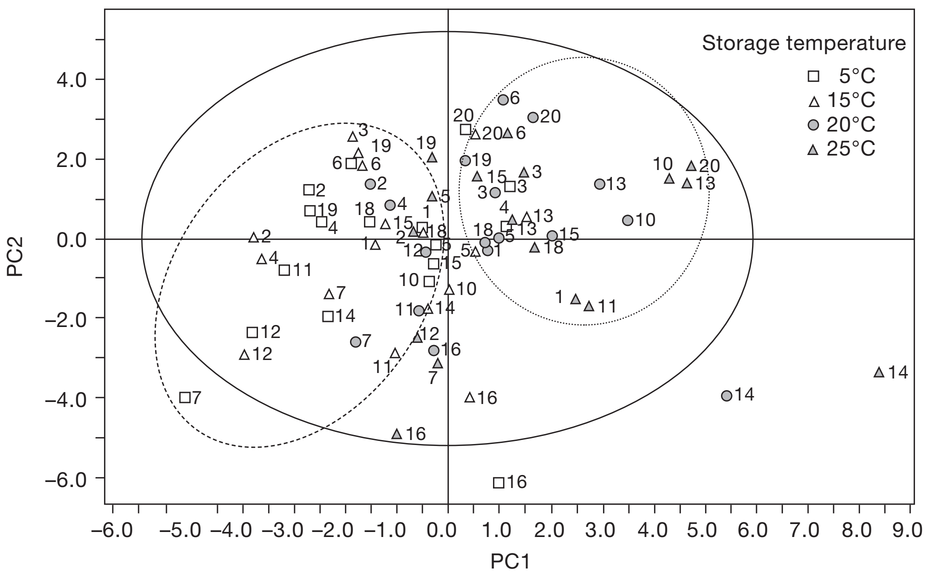

Figure 2. Score plot after performing PCA on the sensorial data matrix. Each symbol (different temperatures) is followed by the number of the panellist.

The ethanol content under all conditions was < 140 mg/100 ml, the threshold required for off-flavour development (Cuquerella and Martínez-Jávega, 1981), and decreased at the end of storage at all temperatures. Similar results have been reported in related studies (Marcilla and Rojas, 2004). Hagenmaier (2000) concludes that the ethanol content provides a good estimate of flavour degradation for oranges cv. Valencia. According to this author, the presence of off-flavours was detected in some cases in oranges with an ethanol content in the range 80-500 mg/100 ml; concentrations of > 500 mg/100 ml produced a clear off-flavour in all cases. In a similar study, the flavour of wax-coated tangerines stored for 7 days at 21ºC was rated markedly less fresh when the ethanol content of the juice was > 150 mg/100 ml (Hagenmaier, 2002).

In the present study, although no significant differences were seen in the instrumentally-determined acidity for the different storage times (Table 2), the sensorially perceived TA decreased significantly over time, probably due to the rise in SSC (Table 1). Similarly, Harker *et al.* (2002) report sensorial differences that failed to correspond to any differences in instrumental measurements. In the present study, the panellists were trained to distinguish between sweetness and sourness as separate tastes, although both flavours interact with one another. The perception of sugar can be masked or accentuated by the presence of acids, as well as some aromatic compounds that impart sweet flavour notes (Malundo *et al.*, 1995). The panellists met after each session and discussed their results, resolved problems or controversies, and asked for additional samples. They commented that it was more difficult to find differences during the two last sessions when the fruit flavour was less strong.

The significant effect of the panellist returning the results [identified in MLR analysis (Table 3) and PCA (Fig. 2)] revealed that the response of these subjects is biased, probably by insufficient training. The main objective of a panel trained for a specific task is to obtain reproducible, reliable and valid sensorial data (Costell, 1992). Thus, additional training sessions were required for the panel to produce more accurate and reproducible results.

The relationships between the sensorial attributes of the oranges kept at different storage temperatures was clearly shown by PCA. The results were consistent, with strong correlations found between sensorially-perceived acidity and sensorially-perceived MI (r = –0.91), and between off-flavours and orange-like flavour (r = –0.80) (Table 5). A smaller but statistically significant direct correlation between sensorial MI and orange-like flavour was also obtained (r = 0.52), which is consistent with results reported for grapefruit juice (Fellers, 1991). Orange-like flavour decreased not as a consequence of an increment in the ethanol content, but because of other, minimal chemical changes that took place during storage.

The main finding of this work is that the reduction in orange-like flavour over storage is related to the presence of off-flavours, probably caused by low concentrations of metabolic compounds resulting from respiratory metabolism. However, the change in TA and MI over storage had a reduced impact on orange-like flavour. The results identify two groups of fruits in terms of the variables measured: those stored at 5 and 15°C, and those stored at 20 and 25°C. Those stored at the lower temperatures were perceived as being more acidic, the only sensorial attribute that positively influenced orange-like flavour. Further research is needed to investigate the relationship between sensorially and instrumentally measured variables in other citrus cultivars.

Acknowledgements

A. Marcilla was supported by a grant from The Spanish National Institute for Agricultural and Food Research and Technology (INIA), Madrid, Spain.

References

ABAD M.I., MARTÍNEZ-JÁVEGA J.M., BEN-ABDA J., MONTERDE A., 2003. Comportamiento en frigoconservación de las naranjas ‘Delta’ y ‘Midknight’. Proc. II Congreso Español de Ciencias y Técnicas del Frío: Avances en Ciencias y Técnicas del Frío-II. Vigo, Spain. pp. 662-670.

BALDWIN E.A., 2002. Fruit and vegetable flavor [on line]. Available in http://www.ba.ars.usda.gov/hb66/023 flavor.pdf [19 July, 2006].

BALDWIN E.A., NISPEROS-CARRIEDO M., SHAW P.E., BURNS J.K., 1995. Effect of coatings and prolonged storage conditions on fresh orange flavour volatiles, degrees Brix and ascorbic acid levels. J Agric Food Chem 43, 1321-1331.

BIOLATTO A., VÁZQUEZ D.E., SANCHO A.M., CARDUZA F.J., PENSEL N.A., 2005. Effect of commercial conditioning and cold quarantine storage treatments on fruit of ‘Rouge La Toma’ grapefruit (*Citrus paradise* Macf.). Postharvest Biol Technol 35, 167-176.

CASCALES A.I., COSTELL E., ROMOJARO F., 2005. Effect of the degree of maturity on the chemical composition, physical characteristics and sensory attributes of Peach, cv. Caterin. Food Sci Tech Int 11, 345-352.

CORRIGAN V.K., HURST P.L., BOULTON G., 1997. Sensory characteristics and consumer acceptability of ‘Pick Lady’ and other late-season apple cultivars. J Crop Hort Sci 25, 375-383.

COSTELL E., 1992. Sensory analysis applied to quality of citrus fruits. Rev Esp Cienc Tecnol Aliment 32, 269-281.

CUQUERELLA J., MARTÍNEZ-JÁVEGA J.M., 1981. Some physiological effects of different wax treatments of Spanish citrus fruit during cold storage. Proc Intl Soc Citricult 2, 734-737.

ECHEVARRÍA G., LARA I., FUENTES T., LÓPEZ M.L., GRAELL J., PUY J., 2004. Assessment of relationships between sensory and instrumental quality of controlled-atmosphere-stored ‘Fuji’ apples by multivariate analysis. J Food Sci 69, 368-375.

ECHEVERRÍA E.D., ISMAIL M., 1987. Changes in sugar and acids of citrus fruits during storage. Proc Fla State Hort Soc 100, 50-52.

FELLERS P.J., 1991. The relationship between the ratio of degrees Brix to percent acid and sensory flavour in grapefruit juice. Food Technol 76, 68-75.

GORNY J.R., HESS-PIERCE B., KADER A.A., 1999. Quality changes in fresh-cut peach and nectarine slices as affected by cultivar, storage atmosphere and chemical treatments. J Food Sci 64,429-432.

GUERINEAU C., DENIS E., SCANDELLA D., NAVEZ B., LANCELIN N., 1999. L´évaluation sensorielle en melon: un outil d´exploration. Infos-Paris 152, 28-33.

HAGENMAIER R.D., 2000. Evaluation of a polyethylene-candelilla coating for ‘Valencia’ oranges. Postharvest Biol Technol 1, 147-154.

HAGENMAIER R.D., 2002. The flavor of mandarin hybrids with different coatings. Postharvest Biol Technol 24, 79-87.

HAGENMAIER R.D., BAKER R.A., 1994. Internal gases, ethanol content and gloss of citrus coated with polyethylene wax, carnauba wax, shellac or resin at different application levels. Proc Fla State Hort Soc 107, 261-265.

HAMPSON C.R., QUAMME H.A., HALL J.W., MACDONALD R.A., KING M.C., CLIFF M.A., 2000. Sensory evaluation as a selection tool in apple breeding. Euphytica 111, 79-90.

HARKER F.R., MARSH K.B., YOUNG H., MURRAY S.H., GUNSON F.A., WALKER S.B., 2002. Sensory interpretation of instrumental measurements 2: sweet and acid taste of apple fruit. Postharvest Biol Technol 24, 241-250.

KE D., KADER A.A., 1990. Tolerance of ‘Valencia’ oranges to controlled atmospheres as determined by physiological responses and quality attributes. J Am Soc Hor Sci 115, 779-783.

LATEUR M., PLANCHON V., MOONS E., 2001. Évaluation par l´analyse sensorielle des qualités organoleptiques d´anciennes variétés de pommes. Biotechnol Agron Soc Eviron 5, 180-188.

LAVILLA T., PUY J., LÓPEZ M.L., RECASENS I., VENDRELL M., 1999. Relationships between volatile production, fruit quality, and sensory evaluation in granny smith apples stored in different controlled-atmosphere treatments by means of multivariate analysis. J Agric Food Chem 47, 3791-3803.

MALUNDO T.M.M., SHEWFELT R.L., SCOUT J.W., 1995. Flavour quality of fresh tomato (*Lycopersicon esculentum* Mill.) as affected by sugar and acid levels. Postharvest Biol Technol 6, 103-110.

MANNHEIM C.H., SOFFER T., 1996. Permeability of different wax coatings and their effect on citrus fruit quality. J Food Chem 44, 919-923.

MARCILLA A., ROJAS C., 2004. Comportamiento de la mandarina 'Marisol' bajo atmósferas controladas. Proc IV Simposio Ibérico, I Nacional y VII Español de maduración y postcosecha. Oeiras, Portugal, Oct 6-9, pp. 249-253.

MARTINEZ-JÁVEGA J.M., CUQUERELLA J., MATEOS M., DEL RÍO M.A., 1991a. Coating treatments in postharvest behaviour of oranges. IFF-IIR Commission C2, D1, D2/3. Technical Innovations in Freezing of Fruit and Vegetables. Davis, California, USA, 9-12 July 1989. pp. 51-55.

MARTÍNEZ JÁVEGA J.M., CUQUERELLA J., NAVARRO P., 1991b. Influencia de la temperatura de conservación y condiciones de almacenamiento en la calidad final de mandarina Nova. III Congreso Mundial de Tecnología de Alimentos. Abstract Book. Barcelona, p. 62.

MAZZUZ C., 2001. Optimización de pre-acondicionamientos térmicos en frutos cítricos con tratamientos cuarentenarios por frío. Doctoral thesis, Politec Univ Valencia, Spain.

MEILGAARD M., CIVILLE G.V., CARR B.T., 1999. Sensory evaluation techniques. CRC Press LLC. Corporate Blvd, Boca Raton, Florida. 354 pp.

PEEPLES W.W., ALBRIGO L.G., 1999. Effects of coating on quality of Florida Valencia oranges stored for summer sale. Proc Fla State Hort Soc 112, 126-130.

PÉREZ-GAGO M.B., ROJAS C., DEL RÍO M.A., 2002. Effect of lipid type and amount of edible hydroxypropyl methylcellulose-lipid composite coatings used to protect postharvest quality of mandarins cv. Fortune. J Food Sci 8, 2903-2910.

PESIS E., AVISSAR I., 1989. The post-harvest quality of orange fruits as affected by pre-storage treatments with acetaldehyde vapour or anaerobic conditions. J Hort Sci 64, 107-113.

PETRACEK P.D., DOU H., PAO S., 1998. The influence of applied waxes on postharvest physiological behavior and pitting of grapefruit. Postharvest BiolTechnol 14, 99-106.

PIANEZZOLA A., NUZZI M., LOVATI F., TESTONI A., 1999. La valutazione sensoriale della qualità delle fragole. Rivista di Frutticoltura e di Ortofloricoltura 61, 42-45.

PORAT R., WEISS B., COHRN L., DAUS A., BITON A., 2005. Effects of polyethylene wax content and composition on taste, quality and emission of off-flavor volatiles in 'Mor' mandarins. Postharvest BiolTechnol 38, 262-268.

POZZAN M.A., CUQUERELLA J., NAVARRO P., 1993. Efecto de diferentes recubrimientos en la comercialización directa de naranjas 'Navelina'. Actas Horticultura 9, 614-619.

PURVIS A.C., 1983. Effects of film thickness and storage temperature on water loss and internal quality of seal-packaged grapefruit. J Amer Soc Hor Sci 108, 562-566.

SALA J.M., 1987. Quality factors of citrus fruit. EEC. Workshop on Measurement of Quality of Citrus Fruit. 1-2 December. Valencia. Spain.

SALVADOR A., 1999. Estudio de la aptitud para la desverdización de nuevas variedades 'Clemenpons', 'Loretina' y 'Beatriz'; y el comportamiento en frigoconservación de las mandarinas 'Ellendalle' y 'Ortanique'. Doctoral Thesis. Politech Univ, Valencia.

SHAW P.E., MOSHONAS M.G., PESIS E., 1991. Changes during storage of oranges pretreated with nitrogen, carbon dioxide and acetaldehyde in air. J Food Sci 56, 469-474.

SHI J.X., PORAT R., GOREN R., GOLDSCHMIDT E.E., 2005. Physiological responses of 'Murcott' mandarins and 'Star Ruby' grapefruit to anaerobic stress conditions and their relation to fruit taste, quality and emission of off-flavor volatiles. Postharvest Biol Technol 38, 99-105.

UNE 87004, 1979. Análisis sensorial. Guía para la instalación de una sala de cata. AENOR, Madrid.

UNE 87023, 1997. Análisis sensorial. Metodología. Ensayo de clasificación por ordenación. Asociación Española de Normalización y Certificación. Madrid. Spain.

VAYSSE P., REYNIER P., VERPONT F., SCANDELLA D., CHENEVARIN S., 1998. L'analyse sensorielle. Méthodologie d'évaluation sensorielle d´un jury entraîné sur pommes. Infos-Paris 147, 38-41.

VÁZQUEZ D.E., 1994. Frigoconservación de mandarinas 'Ellendale' y 'Ortanique' y tratamiento de cuarentena por frío en limón 'Fino'. Master's thesis. Politec Univ Valencia, Spain, 124 pp.